

Research Article

The old good landscape maps: New interpretations enabling ecosystem services assessment of conservation potential at a national scale

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Abstract

The ecosystem services (ES) approach has been widely accepted in environmental policies and management as an adequate platform that can serve as a link between nature and society. Many ES are influenced by the landscape structure. Thus, national-scale landscape mapping can potentially contribute to nature conservation management. However, there are no attempts to directly link the ES assessment with the landscape units at a national level. In this paper, we propose an approach for the transformation of paper copy information from old landscape maps to enable the assessment of ES conservation potential at the national landscape scale. The conceptual scheme of the approach contains three main elements: (i) data acquisition; (ii) landscape and ES assessment data processing; and (iii) mapping of ES potential at a landscape level. The results reveal the landscape heterogeneity based on landscape classification and mapping at a national level and the ES conservation potential based on the analyses of the Natural Heritage (NH) in the country to provide ES. The assessment of ES conservation potential using the national scale landscape mapping allows us to analyze the spatial relationships between the landscapes with high conservation value and the existing nature protection network. The conceptual scheme of the study demonstrates how the results of the ES potential provided by the NH at a national level can be combined with the landscape units from the traditional landscape classification schemes to produce various spatial and statistical metrics that reveal how the national system of protected areas coincides with the areas of high ES conservation value.

Key words: Bulgaria, digitization, GIS, landscape classification, landscape heterogeneity, mapping, nature conservation, spatial data



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Introduction

Conservation and natural resource management have been dominated by approaches that tend to focus on a single sector and a narrow set of objectives that often ignore the wider set of consequences of decision-making (Tallis and Polasky 2009). The ecosystem services (ES) approach has been widely accepted in environmental policies and management as an adequate platform that can serve as a link between nature and society (Burgos-Ayala et al. 2020). The mapping of ES is

a crucial activity because the conservation benefits cannot be identified unless ES can be quantified and valued and their areas of production mapped (Naidoo et al. 2008). The importance of the spatial aspects of ES is stressed also in the EU biodiversity strategy by the requirements for the member states to map and assess the state of ecosystems and their services in their national territory (Maes et al. 2013). The methodological framework for Mapping and Assessment of Ecosystems and their Services (MAES) provides a set of indicators for the assessment of ecosystem condition and mapping of ES that have been developed both at the European level and at the national level in the EU countries. The experience from the different approaches developed through the activities of its implementation is a valuable source of information for developing assessment processes further, especially with regard to their uptake into policy and decision-making (Vári et al. 2024).

Natural heritage (NH) as an outstanding universal value at a national level, refers to the importance of ecosystems, biodiversity, and geodiversity for their existence value. The ecosystems can be considered as the spatial units for its mapping and assessment and the ES concept provides an appropriate basis that can be used as a platform to find solutions to the problems related to the conflicts between conservation and the use of the NH (Nedkov et al. 2021a). However, many ES are influenced by the landscape structure such as the position of ecosystems, functional traits, landscape elements, or land use units in the space (Bastian et al. 2014). Willemen et al. (2012) propose the use of the concept of 'landscape services' as the flow of ES to society provided within a landscape. In general, the landscape approach to the assessment of the benefits from nature to people and the mapping and assessment of ES at the landscape level has also been proposed and applied by some other authors (Termorshuizen and Opdam 2009; Willemen et al. 2010; Müller et al. 2010; De Groot et al. 2010; Prager et al. 2012; Lei et al. 2016; Kivinen et al. 2018; Bezák et al. 2020).

Landscape definitions differ according to the context or type of application (Mücher et al. 2009) and the approaches used to map the landscapes differ in different countries and even within a country. In Germany, the national-level landscape mapping was based on data on national boundaries and current land use while each landscape was assigned to different landscape types and geographical regions (Gharadjedaghi et al. 2004). However, the regional mapping in Saxony was based on classification based on physical-geographic features and landscape units (microgeohores) defined from various sources (Bastian 2000). In the UK, the mapping is based on the concept of a landscape character area (LCA) which is defined as "a distinct recognizable and consistent pattern of elements in the landscape different from another, rather than better or worse" (Somper 2002). The national landscape typology based on LCA for England has 79 generic landscape types (Mücher et al. 2009). In Bulgaria, landscape works are predominantly based on the geosystem concept which defines the landscape as "a specific geographical area forming a system of natural components (rock, soil, air, water, vegetation, and animals), which is changing in time under both natural factors and human activities" (Nedkov and Gikov 2014).

Assessing the ecosystem services using the national scale landscape mapping is a research question that can potentially contribute to nature conservation management. The results of such an assessment could enable us to define whether the rich natural heritage landscapes with high ES conservation value are well protected by the national system of protected areas. The long-term

experience in the mapping of landscapes at a national level (Tzvetkov 2021) and the recent development of the ES mapping and assessment practices in Bulgaria (Nedkov et al. 2024) are a good basis to test such a hypothesis.

The tradition of landscape mapping in Bulgaria is based mainly on the assumption that the landscape is a system of interacting components. This approach is developed particularly in Russia (former USSR) and Eastern Europe (Kondracki 1960, Richling 1984, Romportl and Chuman 2012), and is based on the geosystem paradigm, on soil science, physical geography, and geology, which is not well known to the international readership due to the lack of publications in English (Bastian et al. 2015). The landscape maps are based on hierarchical classification which vary in the number and characteristics of the taxa. The first Bulgarian map at a national level was developed by Petrov (1979) for his doctoral dissertation in 1974 who utilized the five-level classification system proposed by Gvozdetski (1972). The second national scale landscape map was developed by Nikola Todorov for his dissertation in the mid-80's and published in co-authorship with his advisor Velchev et al. (1989, 1992) who utilized the four-level classification system proposed by Beruchashvili (1986). Both maps are prepared using traditional cartographic methods and are available only as paper copies. The lack of digital copies of the landscape maps at a national level is the first research gap to be solved by this study. Furthermore, the hard copies contain distortions in some of the landscape contours that need to be corrected.

The mapping of ES at a landscape scale is a popular topic in the ecosystem research. Bastian et al. (2014) argue this with the assumption that many ES are influenced by the landscape structure, e.g. the position of ecosystems, functional traits, landscape elements or land use units in the space in question. The mapping of ES at a landscape level is argued by Willemen et al. (2010) with the assumption that the landscapes are spatial systems formed by the interaction between human and environment and the specific geographic context is important for both ES supply and demand. The importance of landscape structure on ES provision through multiple landscape-level processes and their influence on ES supply and demand is studied by Metzger et al. (2021). However, there are no attempts to directly link the ES assessment with the landscape units at a national level.

The main objective of this study is to develop an approach that enables the assessment of ES conservation potential at a national landscape scale based on spatial data from old landscape maps. The specific tasks are: (i) to explore the quality of the old landscape map of Bulgaria and transform its content into a GIS database; (ii) to assess the potential of the NH at the national level to provide ES for the needs of nature conservation; (iii) to analyze the spatial relationships between the landscape units, ES conservation potential and the existing nature protection network at the national level.

Materials and methods

Methodological approach

Our study deals with two types of initial data (landscape mapping and ES assessment data), which were generated at different times and using different research approaches. The landscape mapping in Bulgaria at a national scale held in the 80s and 90s of the 20th century used traditional multicomponent analysis and

paper-copy maps. This necessitates preprocessing of the available data, georeferencing, vectorization and validation. The ES assessment data for Bulgaria are available from various studies but only a few of them deal with the entire country at a national level. In this case it was a matter of selecting the most appropriate ES assessment study and adapting the data to the needs of the current study. This means, in particular, reprocessing procedures and analyses related to the conservation purposes of the study. Finally, the two sources are integrated to achieve the main objective directed to exploring the linkages between ES provision at a landscape scale. Therefore, we developed a methodological approach that incorporates different GIS techniques and spatial analyses. The conceptual scheme of the approach contains three main elements: (i) data acquisition; (ii) landscape and ES assessment data processing; (iii) mapping of ES potential at a landscape level (Fig. 1). Each of them is described in more detail in the following subchapters.

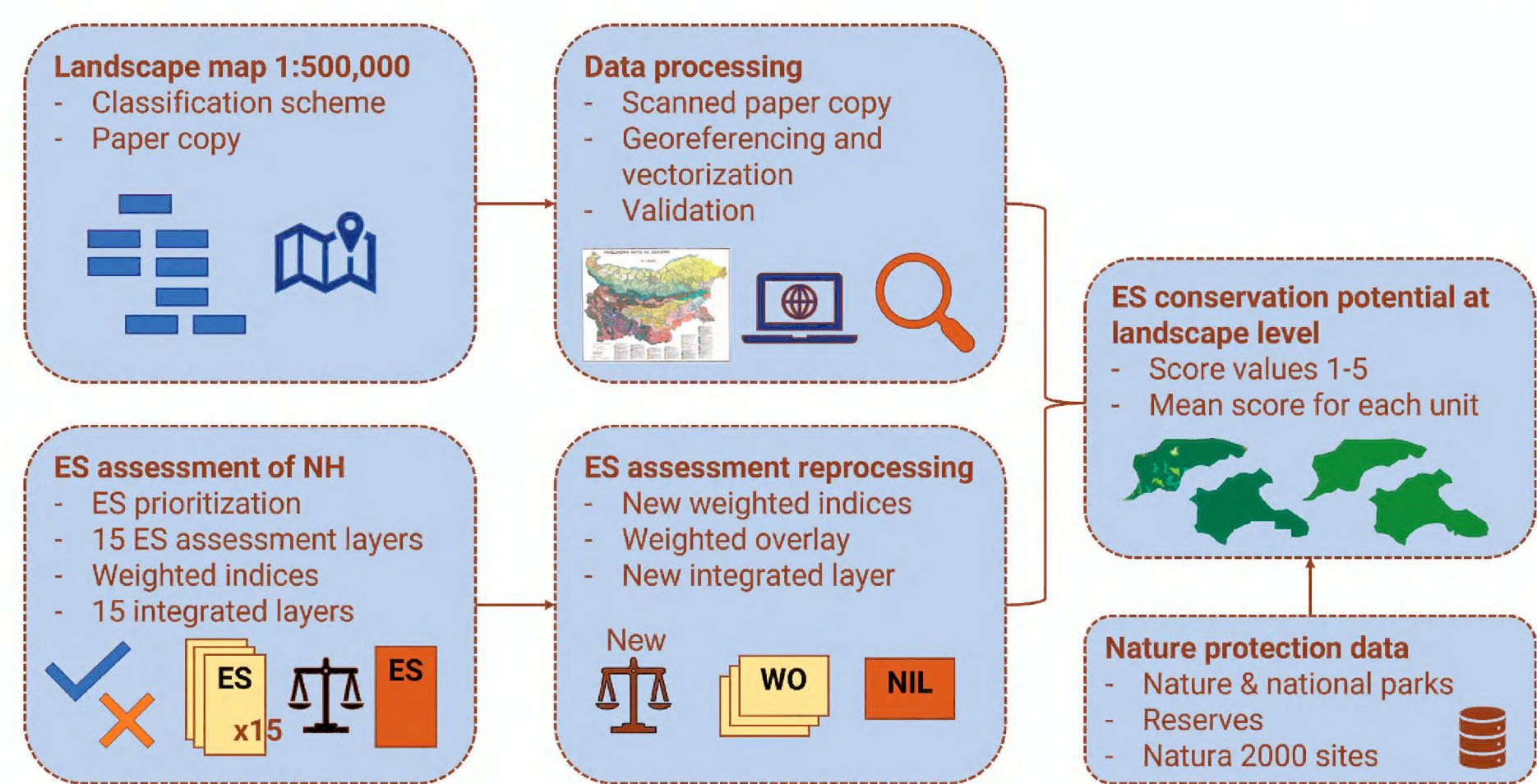


Figure 1. Conceptual scheme of the study.

Initial data

Landscape map of Bulgaria

In this study, we used spatial data for the potential landscapes in Bulgaria. The data were produced based on the second edition of a paper copy map of the landscapes in Bulgaria at a scale of 1:500,000 (Todorov et al. 2004 after Velchev et al. 1989, Velchev et al. 1992). This second edition map was published as a supplementary map in a learning book for students titled “Natural Geography of Bulgaria” (Todorov 2004). The paper map represents the spatial distribution of potential landscapes in the country according to the classification of Velchev et al. (1989, 1992). It consists of four hierarchical levels (class, type, subtype and genus) determined by different factorial criteria including main types of relief and geomorphological forms, hydro-climatic conditions, and natural vegetation. According to the map legend and landscape classification, the map represents two classes (level 1), 17 types (level 2), 29 subtypes (level 3), and 82 genera (level 4).

ES assessment data

For this study we choose the dataset developed under the project “Conceptualization, flexible methodology, and a pilot geospatial platform for access of the Bulgarian natural heritage to the European digital single market of knowledge and information services” which aimed to promote the sustainable use of NH in Bulgaria using the ES as a conceptual background (Nikolova et al. 2021). The conceptual framework used in the project is based on the assumption that the generation of NH for the needs of specific activity can be presented as the linkages between the natural systems and this activity in the form of ES potential, flow, and demand (Nedkov et al. 2021a). The mapping and assessment procedures are fully developed for application at a national level and the dataset from the mapping are available in the form of ES assessment database. The identification and mapping of ecosystem types was made following the MAES topology of ecosystems (Maes et al. 2013) which is organized in two main levels and its structure enables CORINE Land Cover (CLC) data to be applied for spatial delineation. A third level of this typology was developed for Bulgaria (Bratanova-Doncheva et al. 2017; Zhiyanski et al. 2017). The CORINE classes were correlated to the ecosystem subtypes (third level of the MAES typology) to develop a relevance table (Hristova and Stoycheva 2021). The ecosystem services were selected as a results of prioritization procedure (Nedkov et al. 2021b). The application of the methodological framework resulted in generation of 15 GIS layers each of them corresponding to one of the 15 priority ES assessed by various methods at multiple tiers (Table 1). At tier 1, are the services with no uniform data at the national level, which were assessed by expert judgement. The services at tier 2 were provided with statistical data or biophysical parameters at the municipality level that could be interpolated using GIS spatial analyses at the national level. The services at tier 3 were selected for more detailed analyses by different modelling methods. The importance of the different ES for recreation and tourism is not equal and the results from the prioritization were used to define weight indexes that represent these differences (Nedkov et al. 2022). The generation of the GIS layer for each ES was made individually using different spatial unit according to chosen method for indicators quantification (Table 1). The results for each ES were normalized to the 0 to 5 relative scale to be comparable for the overall assessment.

GIS processing and development of a landscape database

To create a digital version of the landscape map of Bulgaria, we used a scanned copy of the original paper map. The paper map was scanned on a large format scanner with a resolution of 300 dpi (Prodanova and Petrova 2020). The scanned copy of the map was then geo-referenced in GIS and used afterward as a basis to create a vector layer by reproducing the contours of the landscapes. The GIS processing was done manually using the “heads-up digitizing” process, meaning that work is being done while looking at the image on the computer screen. A polygon shapefile of the territory of Bulgaria with an

Table 1. Assessed ecosystem services at different tiers and methods. Methods abbreviations: E.A. – expert assessment; Stat. – analysis of statistical data; Sp. Pr. – spatial proxy model; Mod. – modeling methods. Spatial unit abbreviations: Ec. – Ecosystem subtypes; Mun – municipality; Var. – various. (after Nedkov et al. 2022).

Nº	High priority ES	N indicators	Tier	Method	Weight index	Sp. unit
I	Cultivated plants and animals used for nutrition	1	1	E.A	0.6	Ec.
II	Wild plants used for nutrition	1	1	E.A	0.7	Ec.
III	Animals reared to provide energy	1	2	Stat.	0.6	Mun.
IV	Surface water for drinking	3	3	Sp. Pr.	0.8	Var.
V	Regulation of pollution and other harmful impacts	1	1	E.A	0.7	Ec.
VI	Regulation of natural hazards	1	3	Sp. Pr.	0.6	Var.
VII	Maintaining populations and habitats	2	3	Sp. Pr.	0.8	Var.
VIII	Local climate regulation	1	1, 3	E.A, Mod.	0.6	Ec.
IX	Conditions for recreation by biotic systems	2	3	Mod.	1	Var.
X	Science and education value	2	1, 2	E.A, Stat.	0.8	Ec.
XI	Cultural heritage	1	1	E.A	1	Ec.
XII	Aesthetic experiences	2	1, 3	E.A, Mod	1	Ec.
XIII	Symbolic and spiritual value by biotic systems	1	1	E.A	1	Ec.
XIV	Conditions for recreation by abiotic systems	2	3	Mod.	0.9	Var.
XV	Symbolic and spiritual value by abiotic systems	1	1	E.A	1	Ec.

increased % transparency was used for both georeferencing and drawing polygons of the landscapes. The Projected Coordinate System was WGS_1984_UTM_Zone_35N in both cases. The landscape polygons were extracted one by one from the national territory with the application of the ArcMap editing tool “Cut polygon”. Each of the newly cut polygons was given a letter index following the legend of the original map. Another two layers representing major rivers and cities in Bulgaria were used as a reference. During the digitizing process, we noticed an approximate 30–40 km mismatch between the rivers and the riparian landscapes as originally mapped on the scanned and georeferenced copy. Herewith the contours of the Hydromorphous and Subhydromorphous landscapes were corrected where possible.

As a result of the landscape map digitization, new vector data were obtained for the lowest mappable units of the landscape classification at level 4, namely landscape genera. From this layer data, three new layers were subsequently exported to generate the spatial information about class, type and subtype landscapes (levels 1–3). We did this by merging all individual polygons belonging to the same taxa of the upper level. The procedure was repeated three times while data from the previous layer was used for the next one. All GIS layers contain attribute data for landscapes in the respective classification level, index and area calculated in km². Indices were included to be used as short version labeling on map. They represent letter and number combinations following the original classification at each level. Letter indices were transliterated from Cyrillic to Latin and alphabetically ordered according to Bulgarian alphabet as published by Todorov et al. 2004. The final result at this stage of digitization was a GIS database (Suppl. material 1) containing four separate layers and one integrated layer of spatial data about the landscape diversity in Bulgaria according to the four-level landscape classification and map of Todorov et al. 2004.

ES assessment data reprocessing

The ES assessment that produced the data described in previous section was carried out for tourism activity. The overall ES supply map was produced by weighted overlay of the 15 ES layers. For this study, we followed the same approach. First, the results from indicators’ quantification (in vector polygon format) for each of the ES were integrated into a single layer. Then, all vector layers were converted into 50 m raster layers using the ArcGIS “Polygon features to raster data” tool. This ensures the correct spatial overlay between the ES layers. Thus, 15 layers with 50 m resolution representing the priority ES were generated. A weight index representing the significance of each of the 15 ES was calculated. For this study the weight indices were recalculated for the conservation activities. Some of the experts who assessed the ES for the prioritization procedure in the NH assessment were asked to grade the relevance of the selected ES to nature conservation. The values of the weighted indices are given in Table 2. The map of the overall ES potential of the NH to provide ES at the national level was generated using the ArcGIS map algebra tool which enabled us to apply the weighted overlay of the 15 ES raster layers.

Table 2. Weighted indices for mapping of the overall ES conservation potential.

Nº	High priority ES	Weight index
I	Cultivated plants and animals used for nutrition	0.6
II	Wild plants used for nutrition	0.9
III	Animals reared to provide energy	0.7
IV	Surface water for drinking	0.8
V	Regulation of pollution and other harmful impacts	0.8
VI	Regulation of natural hazards	0.9
VII	Maintaining populations and habitats	1
VIII	Local climate regulation	0.9
IX	Conditions for recreation by biotic systems	0.7
X	Science and education value	1
XI	Cultural heritage	0.8
XII	Aesthetic experiences	0.8
XIII	Symbolic and spiritual value by biotic systems	0.8
XIV	Conditions for recreation by abiotic systems	0.7
XV	Symbolic and spiritual value by abiotic systems	0.8

Analyses of the NH potential to provide ES at a landscape level

For the analyses of the NH potential at a landscape level, we need to integrate the spatial data for three sources (ES assessment, landscape map, and protected sites). The NH potential to provide ES is represented by the integrated GIS layer generated at the previous stage. The digital landscape map contains four levels of heterogeneity corresponding to four taxonomic levels of the landscape classification. The first one is too coarse, while the third and fourth are too detailed for the analyses at a national level, therefore we choose the second level (landscape types). The classification criterion at this level is a hydro-climatic condition which led to the delineation of 17

landscape types (Todorov et al. 2004; Velchev et al. 2011). The contours of these landscape units were extracted in a separate layer to be used for the integration of the two sources by using the spatial overlay procedure. The potential of the landscapes to provide ecosystems services is assessed using the 0 to 5 relative scale proposed by Burkhard et al. (2009, 2012). In our case, the matrix contains the 15 ES selected at the previous stages but instead of CORINE Land Cover classes we used the GIS layers for each of the 15 selected ES. Two types of spatial data analyzing the NH potential for conservation purposes were produced at this stage. One is a layer representing detailed information about the scored conservation potential of all ecosystem types within a concrete landscape type. Second is a layer representing the mean scored potential for a single landscape type.

Second part of the NH potential for nature conservation was to analyze the spatial coverage of different landscape types within the existing nature protection network in Bulgaria. Data for protected sites was downloaded from the Environment Executive Agency. Originally, it consisted of six types of protected areas including national parks, reserves, nature parks, natural monuments, maintained reserves, and protected sites. We adapted this data for the purposes of our study by deleting the natural monuments and protected sites feature classes, and combined maintained reserves with reserves in one class. Additional data for Natura 2000 sites in Bulgaria was downloaded from the official website. First, the two layers for both directives for habitats and birds were combined into one by spatial overlay. Since many of the Natura sites fall within the national or nature parks and reserves territories, data for Natura sites was erased from the first layer representing other protected territories (national and nature parks, and reserves) while they have higher conservation level than Naturas.

The newly erased layer was then combined with the parks and reserves one. This last layer consists of all four major types of protected territories in one single layer that is used for spatial and statistical analysis of the landscape types. By overlapping the landscape types with the protected areas' data we generated important information for the spatial distribution of landscapes with highest conservation potential, their characteristics, and showed the real % of nature protection. That allowed us to record the most represented type of protection within a particular landscape, and to highlight both the landscapes with least and most % protected territories.

Results

The application of the proposed approach enabled us to generate three main outputs which correspond to the three main tasks of the study. Firstly, the GIS database developed from the old landscape map enabled us to explore the spatial distribution of the landscape units in the country. Secondly, the reprocessing of the NH potential to provide ES enabled us to develop a map of the ES potential for conservation needs. Thirdly, the spatial analyses of the relationship between the landscape units, the ES potential and the nature protected areas enabled us to identify the landscapes with high potential to provide ES and how they correspond to the existing nature protection network in Bulgaria. The following subchapters present these results in more details.

Spatial distribution of the landscape units in Bulgaria

The developed GIS database enables us to explore the landscape heterogeneity in Bulgaria at different classification levels. The inventory of the digital landscape map shows two classes, 16 types, 28 subtypes, and 82 genera. The landscape heterogeneity at the first level (class) shows a rather simple pattern with two relatively compact areas, which is especially valid for the plain landscapes (Fig. 2A). At the next level (type) the 16 taxa are unevenly distributed throughout the country with total areas ranging from 18% to 1% (Fig. 2B, 3). The highest share of the country is occupied by Mountain Warm-temperate Semi-humid (18%) and Foothills Hilly Warm-temperate Humid (15%). The first one is distributed as a compact area from the central-western to the middle part of the country. The second one is distributed also as a compact area in the northern part of the country. A similar spatial pattern with a slightly lower area has the Plain and Hilly semi-arid (10%) and the Plain and Hilly Temperate Semi-humid (9%).

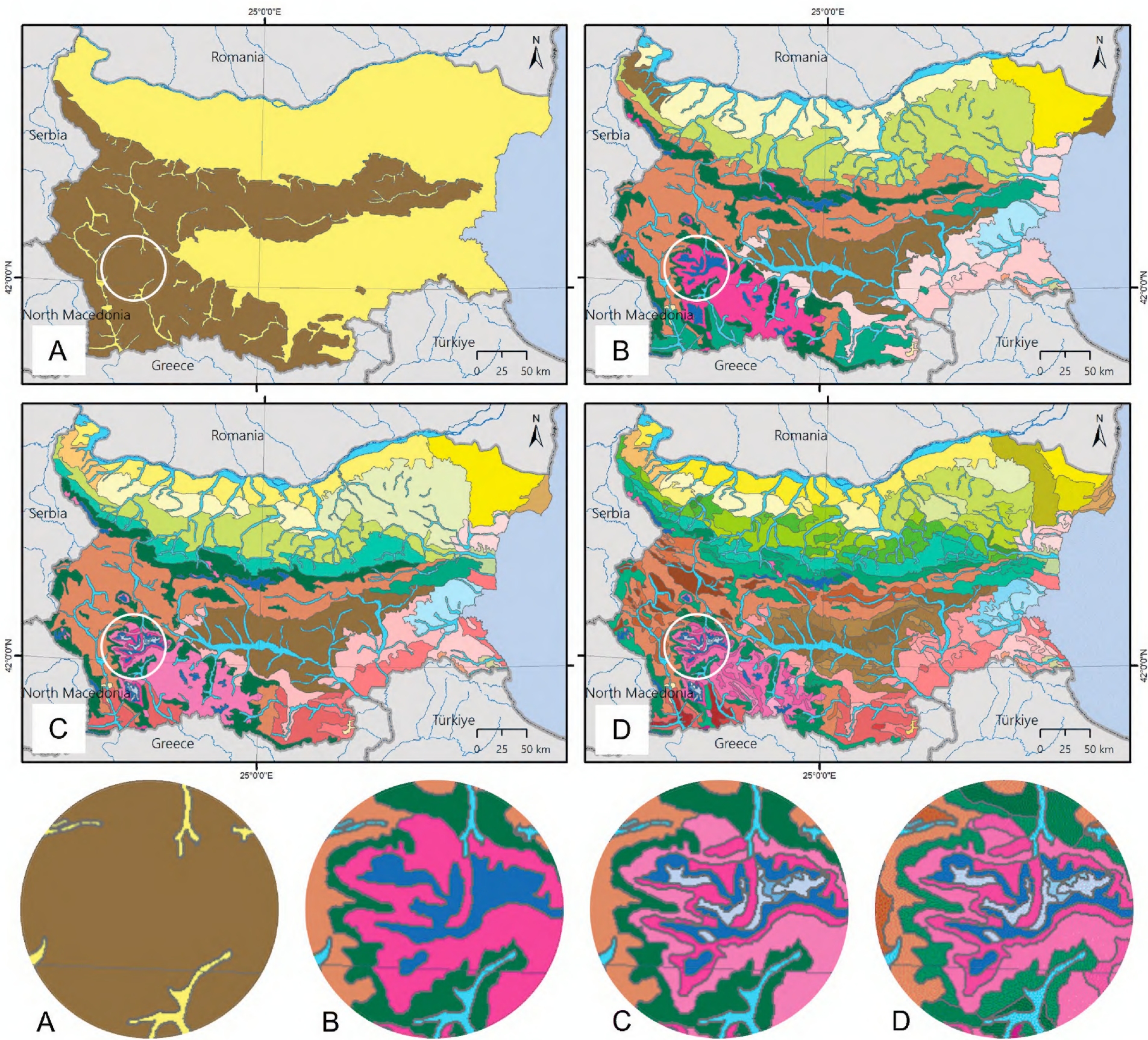


Figure 2. Spatial distribution of the landscape units in Bulgaria at different levels of the landscape classification **A** level 1 **B** level 2 **C** level 3 **D** level 4. Spatial data is available in Suppl. material 1.

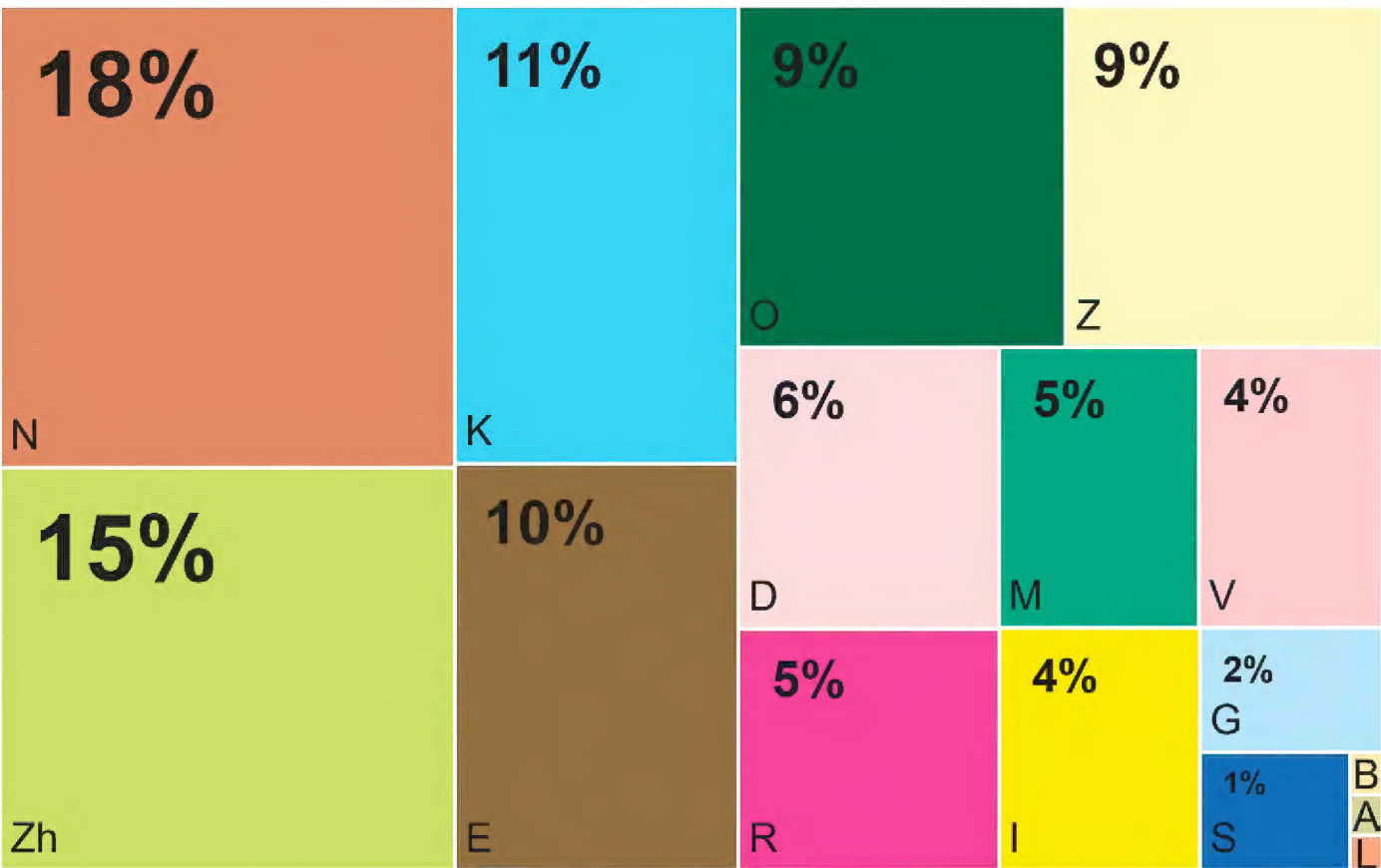


Figure 3. Distribution of the areas covered by the landscapes at level 2 of the classification. Indices are transliterated from Cyrillic to Latin letters and alphabetically ordered according to the original classification. Description of the landscape types **A** (A) hilly subtropical humid **B** (Б) plain and hilly mediterranean semi-humid **V** (В) plain and hilly submediterranean semi-humid **G** (Г) plain submediterranean semi-arid **D** (Д) plain and hilly warm-temperate semi-humid **E** (Е) plain and hilly semi-arid **Zh** (Ж) foothills and hilly warm-temperate humid **Z** (З) plain and hilly temperate semi-humid **I** (И) plain semi-arid **K** (К) hydromorphic and subhydromorphic **L** (Л) mountain subtropical humid **M** (М) mountain submediterranean **N** (Н) mountain warm-temperate semi-humid **O** (О) mountain temperate humid **R** (Р) mountain cold-temperate humid **S** (С) high-mountain grassland.

The Hydromorphic and Subhydromorphic landscapes occupy about 11% of the country. Still, their pattern is totally different from the previous as their areas have linear shapes with scattered distribution throughout the country. Another type with a relatively high share (9%) and scattered distribution is the Mountain Temperate Humid. The rest have a lower extent and three of them occupy less than 1% of the country’s territory (Fig. 3).

The third level (subtypes) represents more detailed differentiation of 28 landscapes within the landscape types. Three of them (D, E, and S) are divided into three subtypes each, six (V, Zh, Z, M, N, and R) are divided into two subtypes each, while the remaining eight have only one subtype each. The landscape heterogeneity at this level is relatively higher, which is more pronounced in the mountain areas (Fig. 2C). At the fourth level of the landscape classification the heterogeneity is the highest with 82 mapping units delineated (Fig. 2D). Their distribution among the landscape subtypes varies between one and six.

Mapping of the NH potential to provide ES for nature conservation needs

The results of the reprocessing of the ES assessment data for the needs of nature conservation enable us to generate a map representing the NH potential to provide ES at a national level (Fig. 4). The map represents the potential of the NH to provide ecosystem services at national level based on the overall score for the 15 selected ES. The values of the 15 ES were normalized

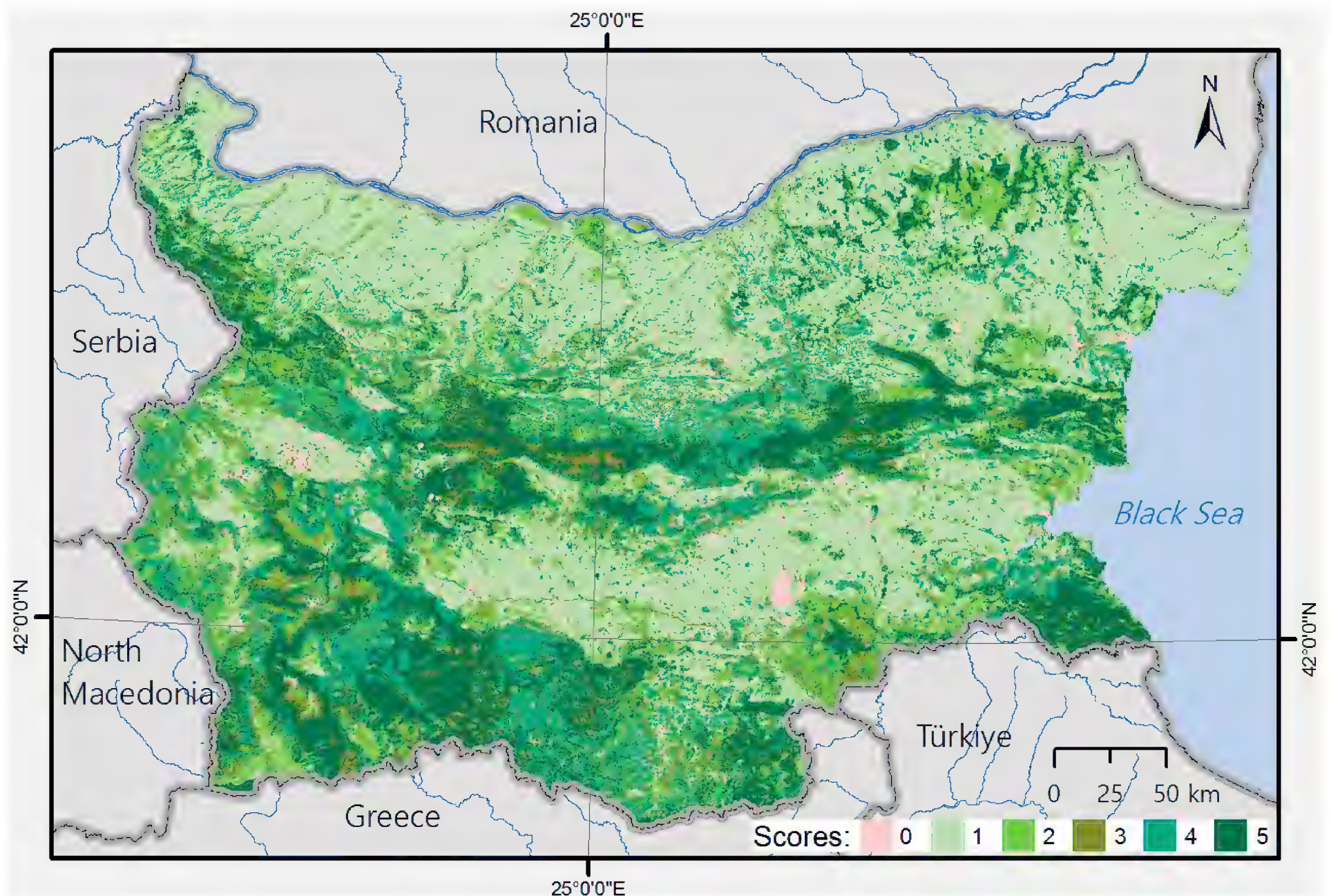


Figure 4. Potential of the natural heritage to provide ES for nature conservation.

to the 0–5 relative scale. It shows that the areas with very high potential are relatively evenly distributed across the country with a pronounced dominance in the mountain areas. They are presented by relatively small patches rather than compact extended areas. However, several clusters with a concentration of very high potential areas could be outlined. The largest one is located in the southwestern part of the country within the high mountain areas of Rila, Pirin, and the Western Rhodopes. It covers predominantly the altitude range between 1000 and 2000 m where the forest habitats (both deciduous and coniferous) are best preserved. The second one covers Central Stara Planina (Balkan Mountain) and Sredna Gora Mountain with similar altitude ranges and predominantly forest habitats. However, the coniferous forests are less present there. Three other clusters can be outlined in the western and eastern parts of Stara Planina Mountain. Two clusters are formed in the low mountains and hilly areas of the Eastern Rhodopes and Strandzha. The last one is located in the lowland-hilly area of the Eastern Danube plain. The areas with very high potential cover 19,118.6 km² which is about 17% of the country. The areas with high potential cover 19,010.3 km² (17%). The areas with moderate and low potential cover about one third of the country distributed again predominantly in the mountain areas but mainly in the highest peaks with bare rocks and no forest cover. The areas with very low potential (about 36%) are located primarily in the plains of the northern and southeast parts of the country. In general, the results show that the whole country has some potential for ES provision and the areas with no potential amount to only 3%.

ES potential of the NH at a landscape level

The potential of the landscapes in Bulgaria to provide ES at the second level of the classification varies between 2.39 and 3.67 (Fig. 5). The highest scores are calculated for the Mountain Subtropical Humid (L), Plain and Hilly Mediterranean semi-humid (B), Hilly Subtropical Humid (A) and Mountain Cold-temperate Humid (R) landscapes. All of them are located in the southern part of the country (Fig. 6). Five landscape types have moderate potential with scores from 2.75 to 3.25. They are located predominantly in the mountains of central, western, and southern parts of the country. The landscapes with low potential have

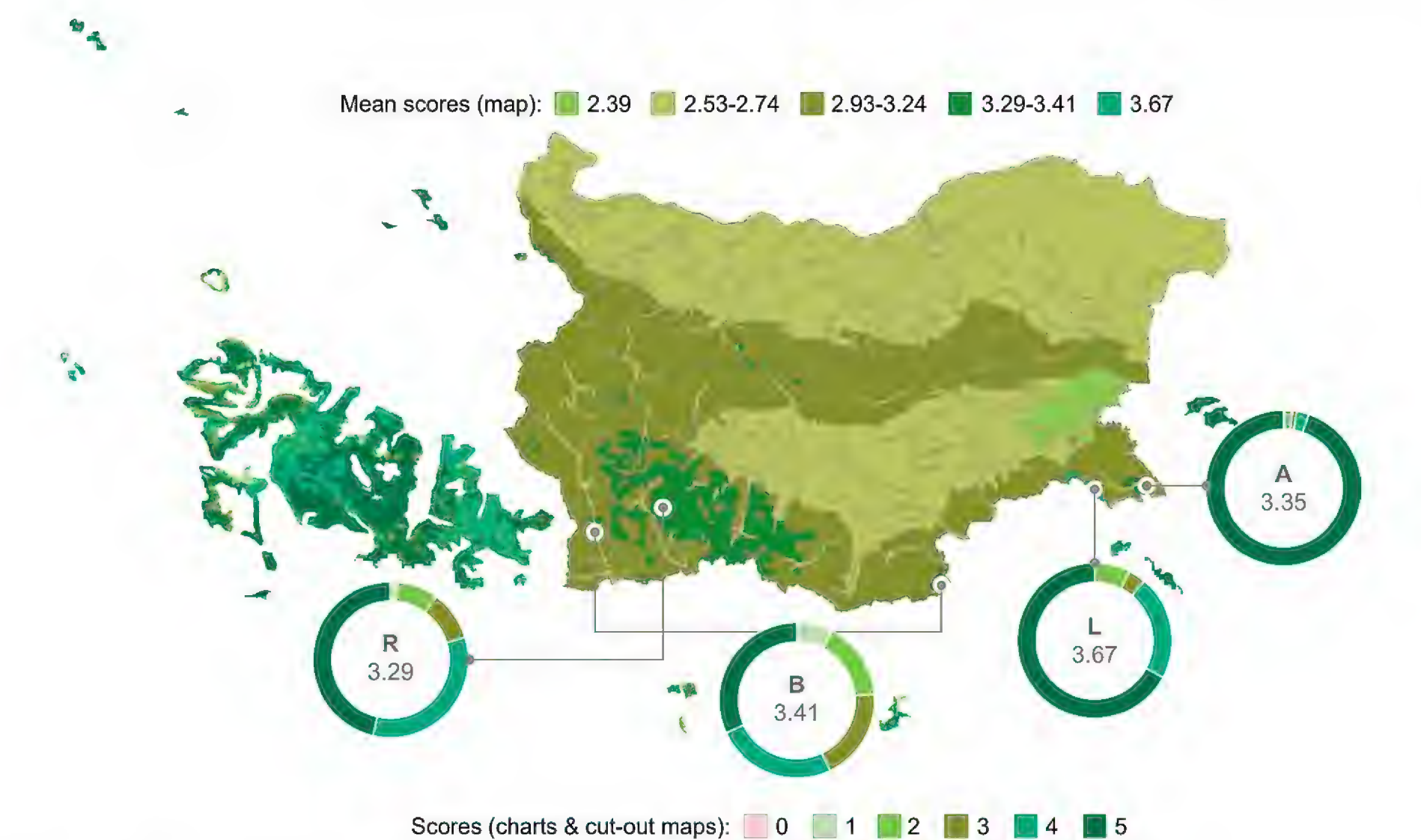


Figure 5. ES potential scores of the landscape types (the names of the indexes are given in Fig. 3).

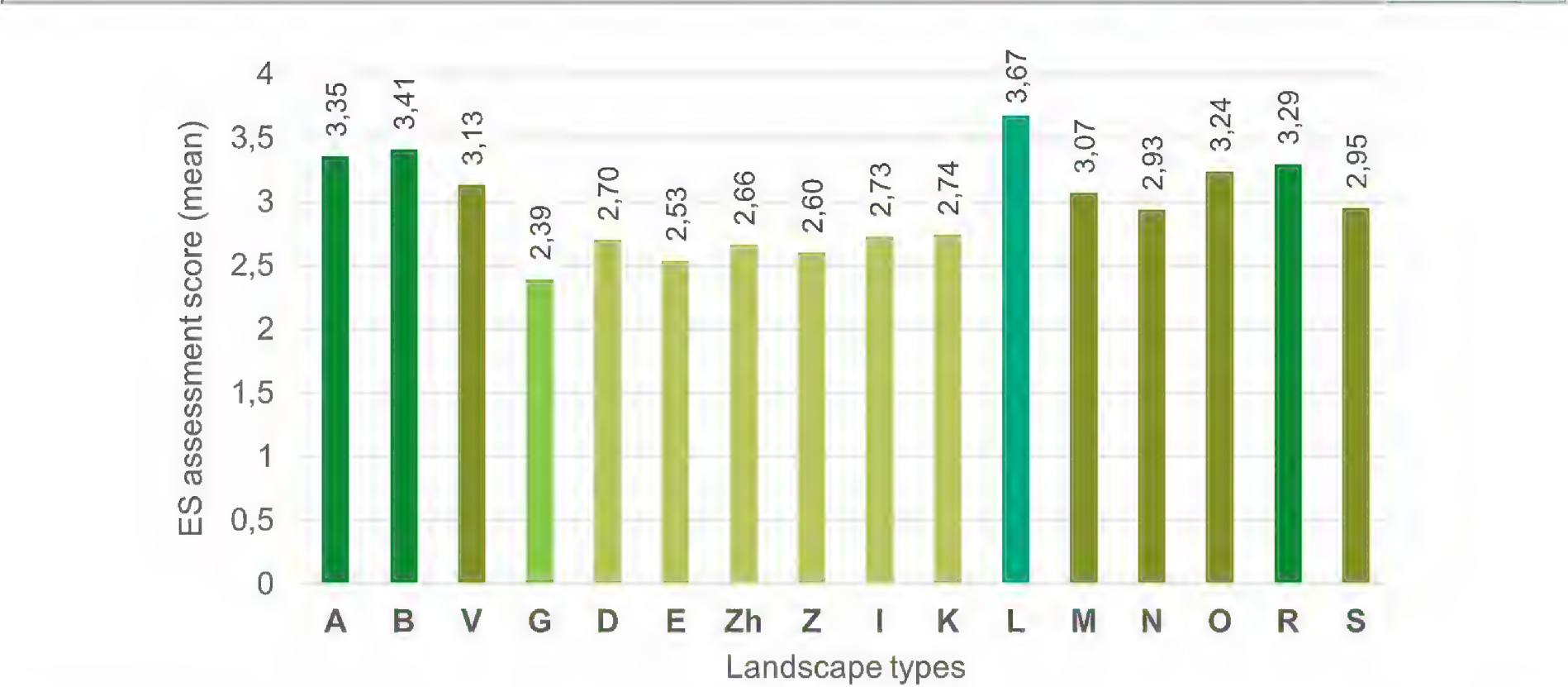


Figure 6. Potential of the landscapes to provide ES at a national level (the landscapes with highest potential are highlighted).

scores varying between 2.25 and 2.75. They cover the lowlands and hilly areas of northern (Danube Plain and Predbalkan) and southeastern (Upper-Thracian and Burgas Plains) part of the country. The lowest scores (2.39) are calculated for the Plain Submediterranean semi-arid landscapes.

The landscape with the highest level of nature protection is the Hilly Subtropical Humid (A), which falls entirely within protected areas (Fig. 7). Its protection is ensured predominantly by the Nature Park regime and partly by Reserve regime. This type is also in the group of landscapes with the highest ES potential. The other two landscape types from this group (B, and L) have high levels of nature protection (85% and 99% respectively) and similar protection patterns dominated by Natura 2000 sites. The fourth landscape type from this group (R) has a lower share of nature protection (67%), but more diverse protected regimes including Nature Park which is missing in the previous landscapes. Five landscape types (G, E, Zh, Z, and I) have a low level of nature protection (below 30%) presented only by Natura 2000 sites. Therefore, there is no IUCN category of protected area in these landscapes. Most of them also have lower scores of ES potential. For the rest of the landscapes, the share of protected area varies between 30% and 65%. A specific case is the landscape type S which has a very high level of protection (95%) and moderate ES potential.

A more precise indicator for conservation purposes is the percentage of the areas with the highest conservation potential (score 5) within particular landscapes under a protection regime. Only the Hilly Subtropical Humid landscape (A) has a very high percentage of such areas under protection. The Mountain Cold-temperate Humid landscape (L) has 52% protection for the areas with very high ES potential while the rest are below 50%. The highest contrast between the average ES score and the percentage of the protected areas with the highest potential is for the Plain and Hilly Mediterranean semi-humid Landscape (B). They have 85% protected landscapes but only 31 of them are with very high ES potential. Some landscapes such as G, E, and Z have an extremely low share (2–3%) of the protected areas with very high ES potential.

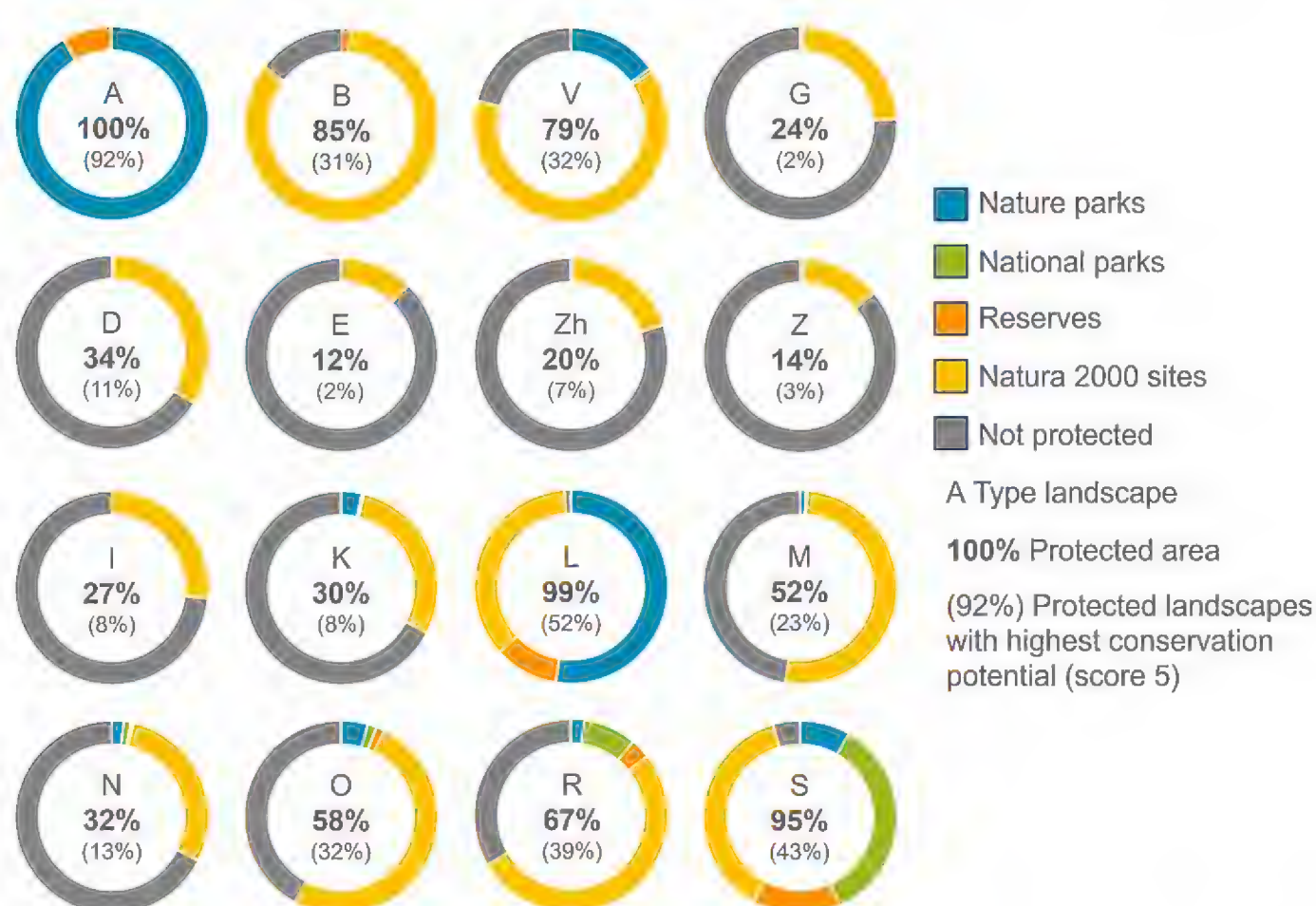


Figure 7. Distribution of the protected areas per landscape and those with highest conservation potential.

Discussion

The geosystem-based landscape works from the 1980s and 1990s contain valuable information that may improve ES supply assessments by strengthening their scientific foundation and elaborating ES in a spatial context (Bastian et al. 2015). However, some of them are still in the paper archives which makes them inappropriate for contemporary research methods. This study proves the need to implement approaches that transform the landscape information from the paper archives to GIS data. The main problem in this transformation is the correction of the inaccuracies of the paper maps which necessitate searching for more precise digitization methods and verification with different data sources. The complex character of the landscape maps makes this verification even more difficult as some of the criteria for differentiation are based on the delineation of potential landscapes that cannot be verified by the existing data. The application of regression models based on the relationship between hydro-climatic indices and the topography is one possible solution (Prodanova 2022; Prodanova et al. 2024).

The landscape map of Velchev et al. (1989, 1992) which was used in this study, also has some shortcomings that should be discussed concerning the uncertainty of the results. Firstly, there is a difference between the taxa at the level type of the classification and the mapping units at the landscape map. The landscape type P (Mountain Temperate Semi-arid and Semi-humid) from the classification is missing in the original paper map as a polygon and consequently in the database. This affects also the results at the lower level of the classification. For instance, at the level subtype according to the classification, there are 29 landscapes, but in our database, there are 28. Secondly, the position of the Hydromorphic and Subhydromorphic (K) landscapes at the second level (type) is contradictory as the main criterion at this stage is the zonal distribution of the hydro-climatic conditions but their formation is determined by the azonal geomorphological conditions (Nedkov and Gikov 2014). Their spatial pattern is totally different from the other types as their areas have linear shapes with scattered distribution throughout the country (Fig. 2), which affects the whole landscape pattern at a national level. Further studies such as fragmentation analyses could be highly affected by this problem as the results with and without this landscape type would be totally different.

The results about the ES potential for conservation provided by the NH at the national scale show some similarities but also differ from the results about the tourism ES potential presented by Nedkov et al. (2022). The main similarity is in the distribution of the areas with very high potential which form similar clusters in both maps. However, the areas with very high ES conservation potential are twice as large. The main difference is in the distribution and share of the areas with low and very low potential. The areas with very low potential (score 1) are much larger on the map of ES conservation potential. The respective areas on the map of ES tourism potential have slightly higher score (2) that corresponds to low potential. Consequently, the areas with very low ES conservation potential (score 1) are more than twice higher than those with very low tourism potential. These differences concern mainly the lowland areas which have a predominance of cultivated lands and cultural landscapes. Their underestimation is a matter of further development of the methodology as there is a growing

interest in the conservation of cultural landscapes based on the awareness that they may be biologically rich (Eriksson 2018).

The landscapes with high conservation potential in Bulgaria are relatively well preserved in terms of coverage by protected areas. This is especially valid for three types (A, B, and L) which have limited extent in areas with very well-preserved natural habitats that facilitate their conservation. However, the share of the strictly protected areas there is low and they remain outside the national parks which are the best managed protected areas in the country. The fourth landscape type with high ES conservation potential (R), has a lower share of protected areas which is due to its larger extent. However, there are more diverse types of protection regimes (including two national parks) that ensure better options for nature conservation management. Natura 2000 network is the only nature protection option for many landscape types such as G, D, E, Zh, Z, I, and M. This protection network seems a good option for areas with a mixture of highly cultivated areas and small natural habitats. A study in the Czech Republic reports low overall effectiveness of the Natura 2000 network but the critically endangered habitats receive maximum protection (Pechanec et al. 2018). Therefore, these small natural habitats can have good protection if the respective Natura sites are well managed. For instance, landscape ecological principles could be applied for comprehensive landscape protection (Janík et al. 2024). The landscapes with lower ES conservation potential have also lower share of protected areas. A specific case is the High Mountain Grassland type (S) which has relatively low ES conservation potential but a higher share of nature protection regimes. One possible explanation could be the ES assessment approach which generally favors the forests and underestimates the low forested landscapes. These analyses provide initial data for the conservation options at the landscape level. However, further analyses are needed to propose better options for nature conservation at the landscape level. The integrated approach for landscape contrast analysis, proposed by Hou and Walz (2016), which integrates both ecotones and small habitats to obtain a detailed and comprehensive description of landscape pattern, is a good option.

Mapping and assessment of ecosystem services can be applied at different levels of scale and complexity which depends very much on the spatial units used for the initial mapping. One of the most convenient spatial units are the CORINE Land Cover classes which ensure timely and easily available data comparable for most European countries. However, CORINE data has its limitations and when more detailed and high resolutions sources are available, they are preferred. Specifically for the matrix approach besides CORINE Land Cover, the EUNIS habitat classification was used for marine and benthic habitats, as well as across different ecosystem types (Campagne et al. 2020). In our case, we combine various data sources (including CORINE) to develop spatial units for each individual ES. They are used for more precise assessment and mapping of ES. The landscape map represents another level of spatial organization and the integration of the ES assessment data into the landscape units ensures different view on the nature conservation pattern.

Conclusion

In this study, we developed and applied an approach that enable us to transform the paper copy information from old landscape maps to GIS data that is appropriate for assessing the ES at a landscape scale. The assessment of

ES conservation potential using the national scale landscape mapping allows us to analyze the spatial relationships between the landscapes with high conservation value and the existing nature protection network. The conceptual scheme (Fig. 1) of the study demonstrates how the results of the ES potential provided by the NH at a national level can be combined with the landscape units from the traditional landscape classification schemes to produce various spatial and statistical metrics that reveal how the national system of protected areas coincides with the areas of high ES conservation value.

The results of the ES potential assessment at the landscape scale and the consequent analyses of the nature protection network enabled us to draw four main conclusions. Firstly, the landscapes with high conservation potential at the national level in the country are relatively well preserved by the existing nature protection network. Secondly, the character of this protection varies between the four landscape types with high conservation value, which is predefined by their size and location. Thirdly, the Natura 2000 network is the only nature protection option for many landscape types, which appears a good option for areas with a mixture of highly cultivated areas and small natural habitats. Fourthly, the landscapes with lower ES conservation potential are less presented in the protected areas, but in some cases, the lower ES potential does not fully correspond to low protection. The latter is a sign of the need for further improvement of the methodology, especially in its ES assessment part.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

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Author contributions

Conceptualization: HP, SN. Data curation: HP, SN. Formal analysis: HP, SN. Funding acquisition: HP, YY. Investigation: HP. Methodology: HP. Resources: HP, SN. Supervision: SN. Validation: HP, YY. Visualization: HP. Writing - original draft: HP, SN. Writing - review and editing: YY, HP, SN.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

References

- Bastian O (2000) Landscape classification in Saxony (Germany) – A tool for holistic regional planning. *Landscape and Urban Planning* 50(1–3): 145–155. [https://doi.org/10.1016/S0169-2046\(00\)00086-4](https://doi.org/10.1016/S0169-2046(00)00086-4)
- Bastian O, Grunewald K, Syrbe RU, Walz U, Wende W (2014) Landscape services: The concept and its practical relevance. *Landscape Ecology* 29(9): 1463–1479. <https://doi.org/10.1007/s10980-014-0064-5>
- Bastian O, Grunewald K, Khoroshev AV (2015) The significance of geosystem and landscape concepts for the assessment of ecosystem services: Exemplified in a case study in Russia. *Landscape Ecology* 30(7): 1145–1164. <https://doi.org/10.1007/s10980-015-0200-x>
- Beruchashvili N (1986) *The Four Dimensions of the Landscape*. Mysl, Moscow, 182 pp. [in Russian]
- Bezák P, Mederly P, Izakovičová Z, Moyzeová M, Bezáková M (2020) Perception of Ecosystem Services in Constituting Multi-Functional Landscapes in Slovakia. *Land* (Basel) 9(6): 195. <https://doi.org/10.3390/land9060195>
- Bratanova-Doncheva S, Chipev N, Gocheva K, Vergiev S, Fikova R. (2017) Methodological framework for assessment and mapping of ecosystem condition and ecosystem services in Bulgaria. Conceptual basis and principles of application. ISBN 978-619-7379-21-1, Clorind, Sofia, 48 pp.
- Burgos-Ayala A, Jiménez-Aceituno A, Rozas-Vásquez D (2020) Integrating Ecosystem Services in Nature Conservation for Colombia. *Environmental Management* 66(2): 149–161. <https://doi.org/10.1007/s00267-020-01301-9>
- Burkhard B, Kroll F, Müller F, Windhorst W (2009) Landscapes Capacities to Provide Ecosystem Services – a Concept for Land-Cover Based Assessments. *Landscape Online* 15: 1–22. <https://doi.org/10.3097/LO.200915>
- Burkhard B, Kroll F, Nedkov S, Müller F (2012) Mapping supply, demand and budgets of ecosystem services. *Ecological Indicators* 21: 17–29. <https://doi.org/10.1016/j.ecolind.2011.06.019>
- Campagne CS, Roche P, Müller F, Burkhard B (2020) Ten years of ecosystem services matrix: Review of a (r)evolution. *One Ecosystem* 5: e51103. <https://doi.org/10.3897/oneeco.5.e51103>
- De Groot RS, Alkemade R, Braat L, Hein L, Willemen L (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecological Complexity* 7(3): 260–272. <https://doi.org/10.1016/j.ecocom.2009.10.006>
- Eriksson O (2018) What is biological cultural heritage and why should we care about it? An example from Swedish rural landscapes and forests. *Nature Conservation* 28: 1–32. <https://doi.org/10.3897/natureconservation.28.25067>

- Gharadjedaghi B, Heimann R, Lenz K, Martin C, Pieper V, Schulz A, Vahabzadeh A, Finck P, Riecken U (2004) Verbreitung Und Gefährdung Schutzwürdiger Landschaften in Deutschland. *Natur Und Landschaft* 79(2): 71–81.
- Gvozdetski NA (1972) Landscape map and scheme of physical-geographical zoning of Caucasus. *Landscape mapping and physical-geographical zoning*. Moscow, Moscow State University, 97–118. [in Russian]
- Hou W, Walz U (2016) An integrated approach for landscape contrast analysis with particular consideration of small habitats and ecotones. *Nature Conservation* 14: 25–39. <https://doi.org/10.3897/natureconservation.14.7010>
- Hristova D, Stoycheva V (2021) Mapping of ecosystems in Bulgaria for the needs of natural heritage assessment. *Journal of the Bulgarian Geographical Society* 45: 89–98. <https://doi.org/10.3897/jbgs.e76457>
- Janík T, Romportl D, Křenová Z (2024) Applying landscape ecological principles in comprehensive landscape protection: Šumava National Park as a case study. *Nature Conservation* 55: 297–320. <https://doi.org/10.3897/natureconservation.55.119797>
- Kivinen S, Vartiainen K, Kumpula T (2018) People and Post-Mining Environments: PPGIS Mapping of Landscape Values, Knowledge Needs, and Future Perspectives in Northern Finland. *Land (Basel)* 7(4): 151. <https://doi.org/10.3390/land7040151>
- Kondracki J (1960) Types of Natural Landscape (Geographical Environment) in Poland. *Przegląd Geograficzny* 32(1–2): 23–33.
- Lei K, Pan H, Lin C (2016) A landscape approach towards ecological restoration and sustainable development of mining areas. *Ecological Engineering* 90: 320–325. <https://doi.org/10.1016/j.ecoleng.2016.01.080>
- Maes J, Teller A, Erhard M et al. (2013) Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. 1st MARS report. Publications office of the European Union, Luxembourg.
- Metzger JP, Villarreal-Rosas J, Suárez-Castro AF, López-Cubillos S, González-Chaves A, Runtig RK, Hohlenwerger C, Rhodes JR (2021) Considering landscape-level processes in ecosystem service assessments. *The Science of the Total Environment* 796: 149028. <https://doi.org/10.1016/j.scitotenv.2021.149028>
- Mücher CA, Klijn JA, Wascher DM, Schaminée JH (2009) A new European Landscape Classification (LANMAP): A transparent, flexible and user-oriented methodology to distinguish landscapes. *Ecological Indicators* 10(1): 87–103. <https://doi.org/10.1016/j.ecolind.2009.03.018>
- Müller F, de Groot R, Willemen L (2010) Ecosystem Services at the Landscape Scale: The Need for Integrative Approaches. *Landscape Online* 23: 1–11. <https://doi.org/10.3097/LO.201023>
- Naidoo R, Balmford A, Costanza R, Fisher B, Green RE, Lehner B, Malcolm TR, Ricketts TH (2008) Global mapping of ecosystem services and conservation priorities. *Proceedings of the National Academy of Sciences of the United States of America* 105(28): 9495–9500. <https://doi.org/10.1073/pnas.0707823105>
- Nedkov S, Gikov A (2014) Landscape differentiation on the northern slopes of the Central Stara Planina and Predbalkan. *Proceedings “30 years department of geography in Veliko Turnovo University”, Ivis*, 28–34. [in Bulgarian]
- Nedkov S, Borisova B, Nikolova M, Zhiyanski M, Dimitrov S, Mitova R, Koulov B, Hristova D, Prodanova H, Semerdzhieva L, Dodev Y, Ihtimanski I, Stoyanova V (2021a) A methodological framework for mapping and assessment of ecosystem services provided

- by the natural heritage in Bulgaria. *Journal of the Bulgarian Geographical Society* 45: 7–18. <https://doi.org/10.3897/jbgs.e78680>
- Nedkov S, Mitova R, Nikolova M, Borisova B, Hristova D, Semerdzhieva L, Zhiyanski M, Prodanova H (2021b) Prioritization of ecosystem services related to the natural heritage of Bulgaria. *Journal of the Bulgarian Geographical Society* 45: 19–30. <https://doi.org/10.3897/jbgs.e73687>
- Nedkov S, Nikolova M, Prodanova H, Stoycheva V, Hristova D, Sarafova E (2022) A multi-tiered approach to map and assess the natural heritage potential to provide ecosystem services at a national level. *One Ecosystem* 7: e91580. <https://doi.org/10.3897/oneeco.7.e91580>
- Nedkov S, Stoycheva V, Prodanova H, Ananiev I, Yordanov Y (2024) Twenty years of ecosystem services research in Bulgaria: Lessons learned and future directions from a geographical perspective. *BioRisk* 22: 33–52. <https://doi.org/10.3897/biorisk.22.125194>
- Nikolova M, Nedkov S, Borisova B, Zhiyanski M, Dimitrov S (2021) Natural heritage as a source of ecosystem services for recreation and tourism in Bulgaria. *Journal of the Bulgarian Geographical Society* 45: 3–6. <https://doi.org/10.3897/jbgs.e79485>
- Pechanec V, Machar I, Pohanka T, Opršal Z, Petrovič F, Švajda J, Šálek L, Chobot K, Filipovová J, Cudlín P, Málková J (2018) Effectiveness of Natura 2000 system for habitat types protection: A case study from the Czech Republic. *Nature Conservation* 24: 21–41. <https://doi.org/10.3897/natureconservation.24.21608>
- Petrov P (1979) A classification system of the landscapes in Bulgaria. *Annual of Sofia University. Faculty of Geology and Geography* 70(2): 159–181. [in Bulgarian]
- Prager K, Reed M, Scott A (2012) Encouraging collaboration for the provision of ecosystem services at a landscape scale—Rethinking agri-environmental payments. *Land Use Policy* 29(1): 244–249. <https://doi.org/10.1016/j.landusepol.2011.06.012>
- Prodanova H (2022) Geoecological state of the landscapes in North-Central Bulgaria (between the Osam River and the Yantra River). Doctoral dissertation. “St. Cyril and St. Methodius” University of Veliko Tarnovo, 143 pp. [in Bulgarian]
- Prodanova H, Petrova M (2020) Assoc. Prof. PhD Nikola Todorov (1955–2018) – A Life Dedicated to Geography. *Journal of the Bulgarian Geographical Society* 42: 115–131. <https://doi.org/10.3897/jbgs.2020.42.17>
- Prodanova H, Nedkov S, Petrov G (2024) GIS-based modelling of landscape patterns in mountain areas using climate indices and regression analysis. *Environmental Modelling & Software* 180: 106160. <https://doi.org/10.1016/j.envsoft.2024.106160>
- Richling A (1984) Typology of Natural Landscape in Poland on Tiie Scale of 1: 500 000. *Miscellanea Geographica* 1(1): 27–32. <https://doi.org/10.2478/mgrsd-1984-010105>
- Romportl D, Chuman T (2012) Proposal method of landscape typology in the Czech Republic. *Journal of Landscape Ecology* 5(3): 24–35. <https://doi.org/10.2478/v10285-012-0057-5>
- Somper C (2002) Countryside Quality Counts: Tracking Changes in England’s Landscape. In: Dramstad W, Sogge C (Eds) *Agricultural Impacts on Landscapes: Developing Indicators for Policy Analysis*. Proceedings from the NIJOS/EOCD Expert Meeting on Agricultural Landscape. Oslo, Norway, NIJOS Report 7.
- Tallis H, Polasky S (2009) Mapping and Valuing Ecosystem Services as an Approach for Conservation and Natural-Resource Management. *Annals of the New York Academy of Sciences* 1162(1): 265–283. <https://doi.org/10.1111/j.1749-6632.2009.04152.x>

- Termorshuizen JW, Opdam P (2009) Landscape services as a bridge between landscape ecology and sustainable development. *Landscape Ecology* 24(8): 1037–1052. <https://doi.org/10.1007/s10980-008-9314-8>
- Todorov N (2004) Natural geography of Bulgaria. Manual for practical classes. Maleo-63, Varna, 168 pp. [in Bulgarian]
- Todorov N, Velchev A, Beruchashvili N (2004) Landscape map of Bulgaria 1:500 000. Cartography Ltd., Sofia. [in Bulgarian]
- Tzvetkov J (2021) Development and state of the art of landscape science in Bulgaria. *Acta Universitatis Carolinae. Geographica. Universita Karlova* 56(2): 195–204. <https://doi.org/10.14712/23361980.2021.13>
- Vári Á, Adamescu CM, Balzan M, Gocheva K, Götzl M, Grunewald K, Inácio M, Linder M, Obiang-Ndong G, Pereira P, Santos-Martin F, Sieber IM, Stępniewska M, Tanács E, Termansen M, Tromeur E, Vačkářová D, Czúcz B (2024) National mapping and assessment of ecosystem services projects in Europe – Participants’ experiences, state of the art and lessons learned. *Ecosystem Services* 65: 101592. <https://doi.org/10.1016/j.ecoser.2023.101592>
- Velchev A, Todorov N, Beruchashvili N (1989) A landscape map of Bulgarian at a scale of 1:500 000. Proceedings of VI congress of the Bulgarian geographers, V. Tarnovo. [in Bulgarian]
- Velchev A, Todorov N, Assenov A, Beruchashvili N (1992) A landscape map of Bulgarian at a scale of 1:500 000. *Annual of Sofia University “St. Kliment Ohridski”, Faculty of Geology and Geography, Book 2 – Geography* 84: 85–107. [in Bulgarian]
- Velchev A, Penin R, Todorov N, Konteva M (2011) Landscape Geography of Bulgaria. Bulvest 2000, Sofia, 235 pp. [in Bulgarian]
- Willemen L, Hein LG, van Mensvoort MEF, Verburg PH (2010) Space for people, plants, and livestock? Quantifying interactions among multiple landscape functions in a Dutch rural region. *Ecological Indicators* 10(1): 62–73. <https://doi.org/10.1016/j.ecolind.2009.02.015>
- Willemen L, Veldkamp A, Verburg PH, Hein L, Leemans R (2012) A multi-scale modelling approach for analysing landscape service dynamics. *Journal of Environmental Management* 100: 86–95. <https://doi.org/10.1016/j.jenvman.2012.01.022>
- Zhiyanski M, Nedkov S, Mondeshka M, Yarlovskaya N, Vassilev V, Borisova B, Bratanova-Doncheva S, Gocheva K, Chipev N (2017) Methodology for assessment and mapping of urban ecosystems condition and their services in Bulgaria. Cloprind, Sofia, 82 pp.

Supplementary material 1

Spatial data for the potential landscapes in Bulgaria

Authors: Hristina Prodanova

Data type: rar

Explanation note: Digitized after Todorov et al. 2004: Landscape map of Bulgaria at a scale of 1:500,000. This rar file contains spatial data (.shp, .lyr), and legend (.pdf).

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